Name: ______________________________________ (   )   Class: _____________

華僑中學
HWA CHONG INSTITUTION
SPECIMEN PAPER B

HIGHER PHYSICS

Level **:** Secondary Three
Duration **:** 1 hour

INSTRUCTIONS TO CANDIDATES

Do not open this booklet until you are told to do so.

Write your name, index number and class on the top of this page.

Answer the questions in **Section A and B** in the spaces provided. All workings must be shown.

In **Section B**, answer only **2 questions** out of the 3 questions.
Staple any graph paper used at the back of the answer script.

INFORMATION FOR CANDIDATES

In **Sections A and B** the intended marks for each question or part of a question are given in brackets [ ]. Any working should be done in the space provided.

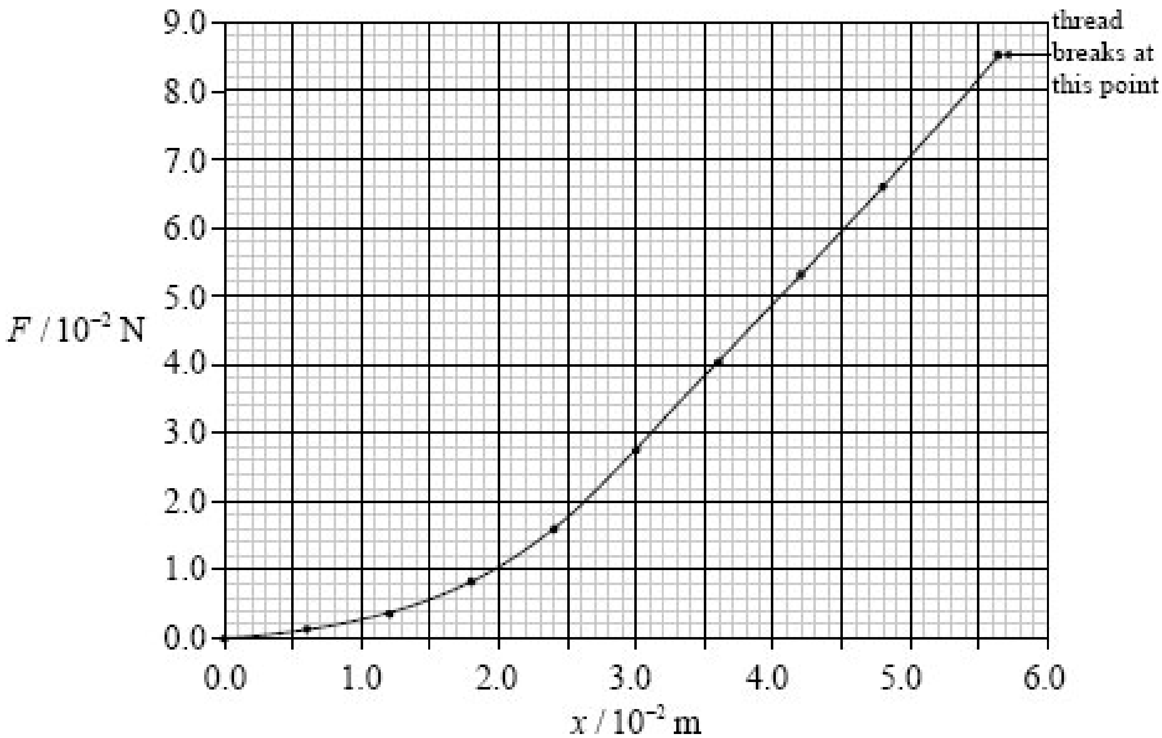
When necessary, take acceleration due to gravity, g to be exactly 10 m s^{-2}.

This question paper consists of 14 printed pages, including this page.

Section A [20 marks]

1. This question is about a spider web.

An experiment was carried out to measure the extension x of a thread of a spider's web when a load F is applied to it. The results of the experiment are plotted as shown below. Uncertainties in the measurements are not shown.



(a) Draw a best-fit line for the data points. [1]

[1]: correct best fit line, based on line passing through the majority of the points.

Continue next page

(b) When a load is applied to a material, it is said to be under "stress". The magnitude P of the stress is given by

$$P = \frac{F}{A}$$

where, A is the area of cross-section of the sample of the material.

Use the graph and the data below to deduce that the thread used in the experiment has a greater breaking stress than steel.

Breaking stress of steel $= 1.0 \times 10^{9}$ N m^{-2}

Radius of spider web thread $= 4.5 \times 10^{-6}$ m

[1]: from the graph breaking load = $8.5(\pm 0.1) \times 10^{-2}$ N

[1]: breaking stress $= \dfrac{8.5 \times 10^{-2}}{3.14 \times (4.5)^2 \times 10^{-12}} = 1.3 \times 10^{9}$ Pa or N m^{-2}

[1]: some statement of conclusion, can e.c.f if calculation is wrong.

....

....

....

.... [3]

Continue next page

(c) In a particular web, one thread has the same original length as the thread used in the experiment. While making the web, the original length of the thread is extended by 2.4×10^{-2} m .

(i) Use the graph to deduce the amount of work required to further extend the thread to the length at which it just breaks is about 1.6×10^{-3} J . Explain your working. [3]

[1]: work = area under graph

[1]: between $(2.4\times10^{-2}, 1.6\times10^{-2})$ and $(5.6\times10^{-2}, 8.5\times10^{-2})$

[1]: $=(1.6\times3.2)\times10^{-4}+\frac{1}{2}(3.2\times6.9)\times10^{-4}=1.6\times10^{-3}$ J

OR

[1]: work = average force × distance / displacement / extension

[1]: average force = 5.1×10^{-2} N ,

[1]: extension = 3.2×10^{-2} m to give 1.6×10^{-3}

(ii) If the thread is not to break due to the impact of a flying insect, then the thread must be capable of absorbing all the kinetic energy of the insect as it is brought to rest by the impact. Determine the impact speed that an insect of mass 0.15 g must have in order that it just breaks the thread.

[1]: K.E. of insect = work needed to break web = 1.6×10^{-3} J

[1]: $v=\sqrt{\frac{2\text{K.E.}}{m}}$

[1]: $=\sqrt{\frac{3.2\times10^{-3}}{1.5\times10^{-4}}}=4.6 \text{ m s}^{-1}$

Allow e.c.f. if value 1.6×10^{-3} J *is not used.*

Impact speed = ... [3]

2. This question is about the physics of falling objects. *(Ignore air resistance for calculation.)*

(a) A 1.80 m tall geologist was walking in a cave. He saw a drop of water fall past his face and splash on the ground. Struck by inspiration, he waited and timed the next drop; it took 0.10 s to fall from the top of his head to the ground.

Calculate the height of the ceiling above his head.

Picture for illustration only. Not to scale with the question.

[1]: $s = ut + \frac{1}{2}at^2$

$1.80 = u(0.1) + \frac{1}{2}(10)(0.10)^2$

[1]: $u = 17.5 \text{ m s}^{-1}$

[1]: $v^2 = u^2 + 2ah$

$17.5^2 = 0 + 2(10)(h)$

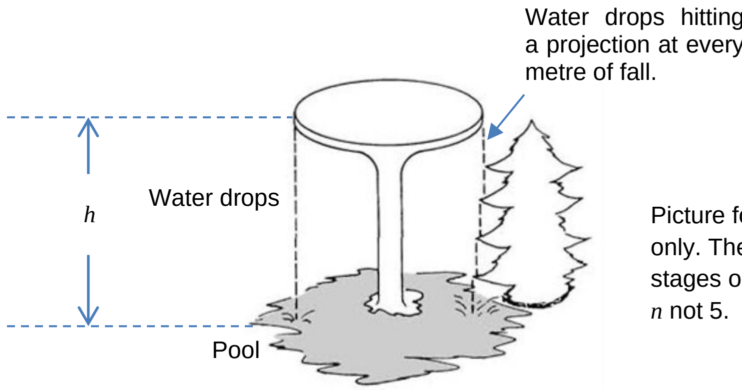
[1]: $h = 15.3$ m

Height above his head = ………………………… m [4]

Continue next page

(b) In a particular fountain, two drops of water fall over the edge of the bowl into a pool h m below. The drop from the left falls directly into the pool. The drop from the right falls 1 m, hits a projection from a nearby Christmas tree and instantaneously loses all its speed and then begins to fall again. After it has fallen another metre, it hits another projection, …, and so on in equal stages until it hits the pool.

How much longer does it take for the drop on the right to reach the pool? Express your answer in terms of the distance fallen on the left h, the number of stages on the right n, and the acceleration due to gravity g. [4]



Picture for illustration only. The number of stages on the right is n not 5.

[1]: for the drop on the left: $h = \frac{1}{2}gt_{left}^2$ or $t_{left} = \sqrt{\frac{2h}{g}}$

[1]: for the drop on the right: $1 = \frac{1}{2}gt_{right}^2$ for 1 stage or $nt_{right} = \sqrt{\frac{2}{g}}n$ for n stages

[1]: $\Delta t = nt_{right} - t_{left}$

[1]: $= \sqrt{\frac{2}{g}}n - \sqrt{\frac{2h}{g}}$ or $= \sqrt{\frac{2}{g}}\left(n - \sqrt{h}\right)$

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(c) The distance an object falls is directly proportional to the square of its time of flight. If it falls 16 feet in 1 s, how long will it take to fall 144 feet?

Recognize that there is no need to convert to S.I. unit for length

[1]: $\frac{144}{16} = \left(\frac{t}{1}\right)^2$

[1]: $t = 3$ s

Time = ... [2]

End of Section A

Section B [20 marks]

Answer two out of the three questions in this section.

3. This question is about body armor.

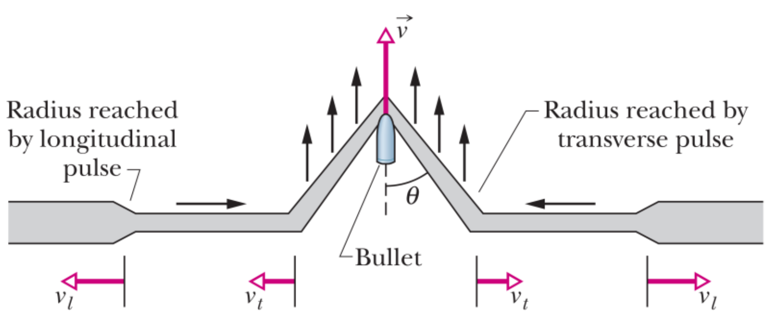
When a high-speed projectile such as a bullet or bomb fragment strikes a modern body armor, the fabric of the armor stops the projectile and prevents penetration by quickly spreading the projectile's energy over a large area. This spreading is done by longitudinal and transverse pulses that move *radially* from the point of impact, where the projectile pushes a cone-shaped dent into the fabric.

The longitudinal pulse, racing along of the fibers of the fabric at speed v_l ahead of the denting, causes the fibers to thin and stretch, with the material flowing radially inward into the dent. One such radial fiber show in the figure below. Part of the projectile's energy goes into this motion and stretching.

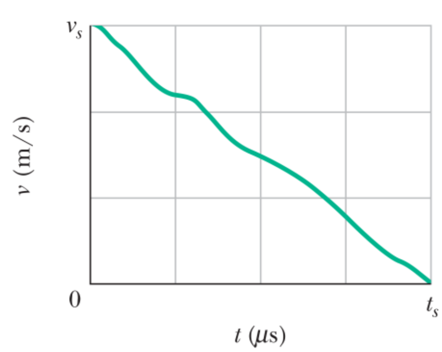
The transverse pulse, moving at a slower speed v_t , is due to the denting. As the projectile increases the dent's depth, the dent increases in radius, causing the material in the fibers to move in the same direction as the projectile (perpendicular to the transverse pulse's direction of travel). The rest of the projectile's energy goes into this motion. All the energy that does not eventually go into permanently deforming the fibers ends up as thermal energy.

The graph below shows the speed v versus the time t for a bullet of mass 1.02×10^{-2} kg fired from a .38 Special revolver directly into the body armor. The scales of the vertical and horizontal axes are set by $v_s = 300$ m s^{-1} and $t_s = 40.0 \times 10^{-6}$ s .

Take $v_l = 2.00 \times 10^3$ m s^{-1} and the half-angle θ of the conical dent to be 60.0° .



Side view of the bullet impact. The transverse radius (dent) is smaller than the longitudinal radius (thinned region).



Speed – time graph of the bullet.

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(a) Calculate the radius of the thinned region at the end of the collision.

Recognize that radius of thinned region is the distance travelled by the longitudinal pulse,

[1]: $r_l = v_l t = (2000)(40 \times 10^{-6})$

[1]: $= 8.0 \times 10^{-2}$ m

Radius = ... [2]

(b) Calculate the penetration depth d of the bullet into the armor. State the assumption for your calculation.

[1]: Assuming the acceleration to be constant (justified by the near-straightness of the curve),

[1]: $v^2 = u^2 + 2ad$ or $d = \dfrac{(300)^2 (40 \times 10^{-6})}{2(300)}$

[1]: $d = 6.0 \times 10^{-3}$ m

$d =$ .... [3]

(c) Calculate the radius of the dent.

Recognize that the radius forms the legs of the right angle triangle (opposite from $\theta = 60^{\circ}$),

[1]: $\tan 60.0^{\circ} = \dfrac{r}{d}$ or $r = d \tan 60.0^{\circ}$

[1]: $r = 1.0 \times 10^{-2}$ m

Radius = ... [2]

(d) In the previous calculations, we have implicitly assumed that the person wearing the body armor remains stationary. In reality, the wearer is often thrown back due to the impact from the bullet.

How will the values of the radii of the thinned region and the dent change if the wearer is moved back during the impact? Explain your answer.

[1]: recognize that a smaller amount of the bullet's kinetic energy is transferred to armor

[1]: impact speed is reduced / time for the impact < 40 μs

[1]: consequently, r_{long} and r_{trans} will be smaller

Answers based solely on energy analysis without sufficient justification, award 2 m max.

[3]

4. This question is about jogging on a hot day.

When jogging strenuously, an average runner of mass 68.0 kg and a surface area of 1.85 m^2 produces energy at a rate of 1300 W, 80% of which is converted to thermal energy. The jogger radiates heat, but actually absorbs more heat from the hot air than he radiates away. At such high levels of activity, the skin temperature can be elevated to 33.0 ^{o}C rather than the usual 30.0 ^{o}C. The only way for the body to get rid of this extra heat is by evaporating water (perspiring).

(a) How much thermal energy per second is produced just by the act of jogging?

[1]: $P_{jog} = (0.80)(1300)$

[1]: $= 1.04 \times 10^3$ W

No penalty if the student write the unit as J.

Thermal energy per second = ... [2]

Continue next page

The power loss by radiation P is given by the Stefan-Boltzmann equation:

$$P = A\sigma\left(T_{man}^4 - T_{environment}^4\right)$$

A: surface area of the object,
σ: Stefan constant; $\sigma = 5.67\times10^{-8}$ W m^{-2} K^{-4} ,
T: temperature in kelvins.

(b) How much net heat per second does the runner gain from radiation if the air temperature is 40.0 ^{o}C ?

[1]: $P_{loss} = (1.85)\left(5.67\times10^{-8}\right)\left([306]^4 - [313]^4\right)$

[1]: $= -87.1$ W $\Rightarrow$ gain $= 87.1$ W

Rate of heat gain = ... [2]

(c) Calculate the total excess heat per second which the body must remove to maintain a constant body temperature

[1]: Total power loss $= 1040 + 87 = 1130$ W

Required rate of heat loss = ... [1]

(d) How much water must the jogger's body evaporate every minute due to this activity?

Heat of vaporization of water at body temperature is 2.42×10^6 J kg^{-1}.

[1]: In 1 min, the runner must dispose $(60)(1130) = 6.78 \times 10^4$ J.

[1]: $m = \dfrac{Q}{L_V} = \dfrac{6.78 \times 10^4}{2.42 \times 10^6}$

[1]: $= 0.0280$ kg

Allow e.c.f.

Mass of water loss $=$ .... [3]

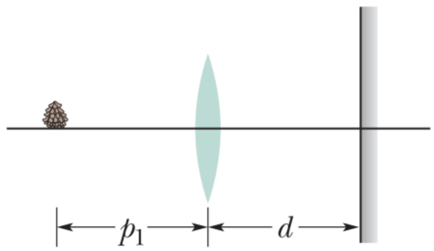
(e) It is recommended that a jogger in such a hot environment has to drink 1-litre of water for every 30 minutes of jogging. Is this amount sufficient to replenish the water loss due to evaporation? Justify your answer. (Show mathematical workings if necessary) [2]

[1]: In 30 min, runner loses $(30)(0.028) = 0.84$ kg

[1]: 1 litre of water $=$ 1 kg of water > 0.84 kg of water loss , hence sufficient.

5. This question is about optics. (*Solve this question using either optics equations or graphical methods.*)

In the figure below, a pinecone is at the distance $p_1 = 1.0$ m in front of the lens of focal length $f_1 = 0.50$ m ; a flat mirror is at a distance $d = 2.0$ m behind the lens. Light from the pinecone passes rightward through the lens, reflects from the mirror, passes leftward through the lens and form a final image of the pinecone.



(a) Calculate the distance between the lens and the final image.

[1]: image formed by converging lens: $i = \left(\frac{1}{f} - \frac{1}{p}\right)^{-1} = \left(\frac{1}{0.50} - \frac{1}{1.0}\right)^{-1}$

[1]: $= 1.0$ m (right of the lens or 1.0 m in front of the mirror)

[1]: location of mirror image is 1.0 m to the right of mirror *OR* 3.0 m to the right of the lens.

[1]: final image by lens: $i_{final} = \left(\frac{1}{f} - \frac{1}{p_{final}}\right)^{-1} = \left(\frac{1}{0.50} - \frac{1}{3.0}\right)^{-1}$

[1]: $= 0.60$ m (to the left of the lens)

Final image distance = ... [5]

Continue next page

(b) Calculate the overall lateral magnification of the pinecone.

Hint: the overall magnification is the product of the magnifications of the lens and the mirror.

[1]: lateral magnification $m = \left(-\frac{i}{p}\right)\left(-\frac{i_{final}}{p_{final}}\right)$ or $\left(-\frac{1.0}{1.0}\right)\left(-\frac{0.60}{3.0}\right)$

[1]: $= +0.20$

lateral magnification $=$ .... [2]

(c) Based on your previous answers, state whether the image is real or virtual. Justify your answer.

[1]: final image is real $\left(\text{since } i_{final} > 0\right)$ or based on drawing; e.c.f. allowed.

[2]

(d) Write a short explanation on how you can determine if the final image is inverted or not, relative to the pinecone.

[1]: the image has the same orientation as the object $\left(\text{since } m > 0\right)$. or based on drawing [1]

Or based on whether m is positive or negative. Or (drawing) final image's arrow's direction.

END OF PAPER